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cc: Mike



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U.S. GEOLOGICAL SURVEY

Utah Water Science Center
2329 Orton Circle
Salt Lake City, Utah 84119-2047

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OCT 17 2013

DIV. OF OIL, GAS & MINING

To: Rebecca Doolittle, District Geologist, BLM, Moab, UT
From: Tom Marston, Hydrologist, USGS, Salt Lake City, UT
Date: August 5, 2013
Re: **Technical Assistance:** Technical review of groundwater model in "*Updated backfill evaluation for the Centennial Pit at the Lisbon Valley Mine, Utah*"

Thank you for the opportunity to review the groundwater model associated with the subject of this report. After reviewing the three models supplied by Arcadis, I have a number of comments concerning the modeling effort and the applicability of the three models as numerical approximations of the past, present, and future natural conditions that exist at the Lisbon Valley Mine. My comments related to the results of the modeling effort by Arcadis are summarized below. In addition, I have included figures produced in GW_Chart (Winston, 2000) to illustrate some of my findings.

1. In the "Hydrogeologic Conceptual Model" section the report refers the reader to the 2009 Annual Update of the Lisbon Valley Hydrogeologic System Evaluation (Whetstone, 2010) to find the source material for construction data in the model. This report mirrors data presented in earlier reports produced by Adrian Brown Consultants, Inc. in that it describes the aquifer system for Lisbon Valley as highly compartmentalized by structural faulting. It also describes the characteristics of both the upper aquifer (Burro Canyon) and the deep aquifer (Navajo) in terms of areal occurrence, water levels, and previously obtained hydraulic properties. The construction of each of the three models supplied by Arcadis is generally in agreement with observed lithology in the Centennial Pit area of the Lisbon Valley Mine, however, the geometry of the lithology is not uniform from model to model and is not represented numerically the same in all three models (discussed separately under 2. and 3.) Some conceptual assumptions have been made during model construction that need to be supported or referenced:
 - a. A no-flow boundary completely surrounds the upper aquifer. The supporting arguments for this indicate that faulting associated with the underlying salt dome has completely offset a portion of the Burro Canyon aquifer and juxtaposed it with either low permeability lithologies or well developed fault gouge. There is no reference in the text to refer the reader to why this assumption is being made. This argument is only made for the upper aquifer, but no explanation is given for why the same conditions would not exist in the lower aquifer, as it is likely bounded by the same fault conditions.
 - b. The lower aquifer is simulated as a constant head boundary, and is the only point of discharge for this model. No explanation is given to support this assumption.

- c. The report refers to previous aquifer tests that have been completed to characterize the hydrologic system near the Lisbon Valley Mine. A range of values of aquifer storage from these tests would be useful in making a comparison to the values used in the model. In addition, if there is any analysis associated with the aquifer tests that suggests a no-flow boundary is encountered, this would be useful to include in strengthening an argument for simulating the no-flow boundary in the upper aquifer in the model.
- 2. After evaluating the water budget outputs for the steady state model (LV-1) and the transient model (LV-TR3), a difference in the thickness of Layer 11 of both models was noted. In the steady state model the thickness of Layer 11 is 490 ft., while in the transient model the thickness of Layer 11 is 330 ft. This difference results in an elevated flux through the Layer 11 in the transient model. The result of this change is seen in the relationship between recharge and the constant head boundary in the Navajo Aquifer in the transient model (fig. 1). If the two models were the same in terms of hydraulic properties and geometry, the transient model would begin with recharge equal to constant head discharge (steady-state conditions), inducing a stress on the system (well pumpage) would then decrease the amount of discharge from the constant head boundary. The transient model in its current form does not illustrate this relationship; instead the model begins with 5,400 ft³/day discharging through the constant head boundary with a steady recharge rate of 4,137 ft³/day. The discharge rate at the end of the transient model is 4,900 ft³/day, still well above the recharge rate. This indicates that some of the drawdown simulated by the model is attributed to the increased flux across Layer 11 due to a change in aquifer geometry. If this is a mistake, calibration would be impossible if the geometry of the model is incorrect, due to the fact that water levels are changing in response to different hydraulic properties than were calibrated to in the steady state model and not withdrawal stress alone. If this is not a mistake, there is no narrative that describes why this was done.
- 3. The report cites one well (Well MW96-7A) as being utilized in calibration of the model. In addition, the observed data from this well used to assess the calibration of the model is limited to data from 2008 and 2009, while data is available from late 2004 through 2009. If this is the only observed data that was used during model calibration the argument for having a calibrated model is weak for the following reasons:
 - a. Multiple observation wells are available as shown in Figure 2 from the 2009 Annual Update of the Lisbon Valley Hydrogeologic System Evaluation (Whetstone, 2010). All of these observations should have been used to calibrate the model or a reason given for not using these data should be provided.
 - b. The time period that correlates to the observed data in Well MW96-7A represents a less-stressed system in comparison to pumping that occurred from 2004 through 2007, which would be useful in assessing the match of observed drawdown and recovery in nearby wells (fig. 2). The use of non-approximated pumpage and water levels from nearby monitoring wells for the entire period of record (2004 through 2009) is essential for calibration of hydraulic conductivity, specific yield, and specific storage. There is no reason stated for non-use of the observed data from previous years.

4. Generally, the predictive model (LV-TR9_5%) is an independent model from the previous steady state and transient models in regards to both construction, and initial conditions. The previous models use a 12 layer construction with 10 layers that represent the Burro Canyon Formation, 1 layer representing the Morrison Formation, and 1 layer representing the Navajo Formation. The predictive model is a 3 layer model, and differs from the previous models by representing the Burro Canyon Formation as 1 layer. This difference in construction changes the hydraulic properties, especially in regards to vertical conductance, and affects the flow properties of the model. In addition, the ending conditions from the previous transient model are not used in the predictive model, instead starting heads are set to one altitude for the entire Burro Canyon Formation at the beginning of the predictive simulation. It is unclear why the post-stressed heads for the transient model were not used, as the predictive simulation must re-equilibrate from an artificial starting condition which in turn masks any process that is occurring in the initial period of the predictive model.
5. Overall the wording in the report is confusing. Clearly, there are three separate models: a steady-state, a transient, and a predictive. The report blends pieces of construction, calibration, and results for all three models into one discussion. As previously stated, each one of these models is different from one another in terms of construction, starting conditions, and discretization. To illustrate this point, Figure B2 in the report shows only a representation of the predictive models spatial discretization. The steady-state and transient models lack the fine discretization that is shown in Figure B2.

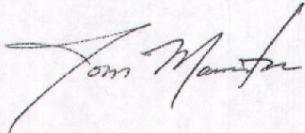
In my opinion, the current models that are being utilized for the Lisbon Valley Copper Mine do not adequately represent the hydrologic system that exists there and cannot be confidently used to predict groundwater conditions that will exist on-site in the future. This opinion is based primarily on the reasons summarized below. The accuracy with which the steady state model represents the actual system is undetermined as the assumptions (correlation of Layer 11 vertical hydraulic conductivity and areal recharge, no-flow boundaries, constant head in Layer 12) stated to produce the water-levels are not clearly represented. The transient model is discretized differently (representation of the system using different layer thicknesses) resulting in simulated changes in storage and water levels that are not the result of simulated stresses alone. The predictive model is also different from the steady state and transient models in terms of construction and initial conditions, thus the accuracy of the predictions cannot be determined. Please feel free to contact me (email: tmarston@usgs.gov; phone: 801-908-5030) if you have any questions or need further clarification on my review of the models and the subject document.

References

Whestone Associates Inc, 2010, 2009 Annual Update of the Lisbon Valley Hydrogeologic System Evaluation, Prepared for Lisbon Valley Mining Co.

Winston, R. B., 2000, Graphical User Interface for MODFLOW, Version 4: U.S. Geological Survey Open-File Report 00-315, 34 p.

Sincerely,



Tom M. Marston
Hydrologist

Copy to: Terry Snyder, BLM State Office, Salt Lake City, UT

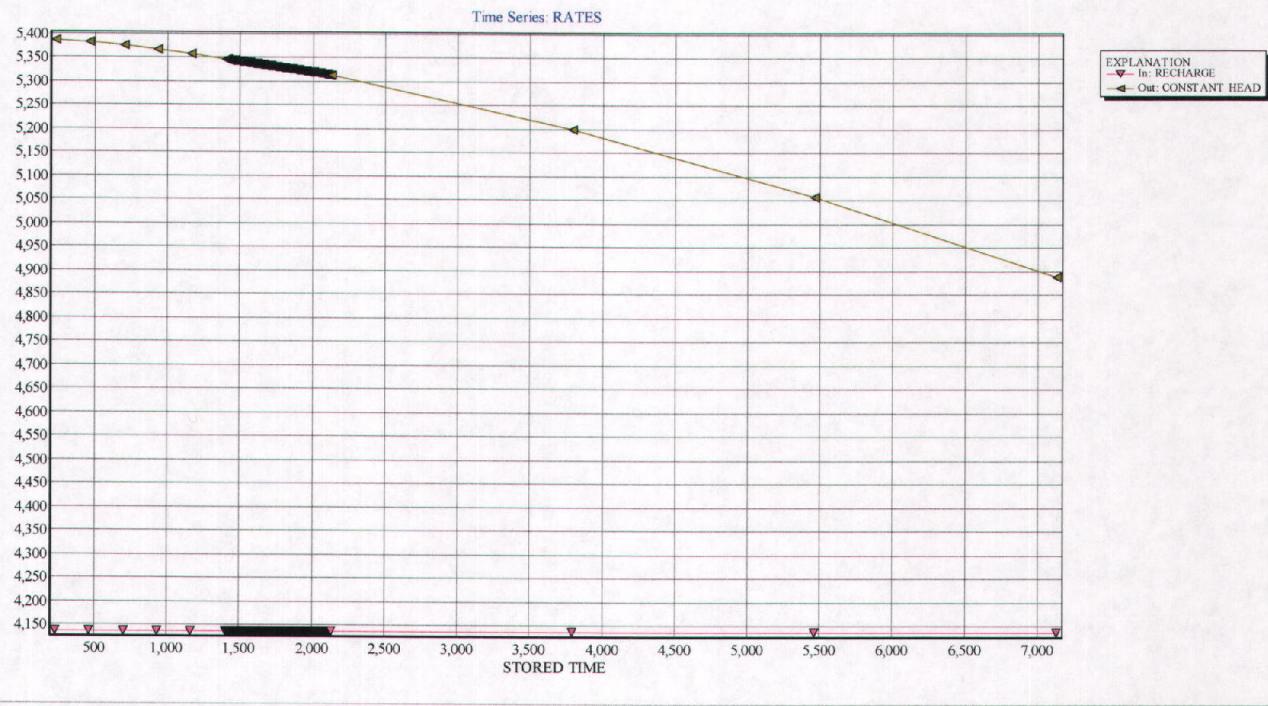


Figure 1
Rates of recharge and constant head discharge for the transient model LV-TR3.

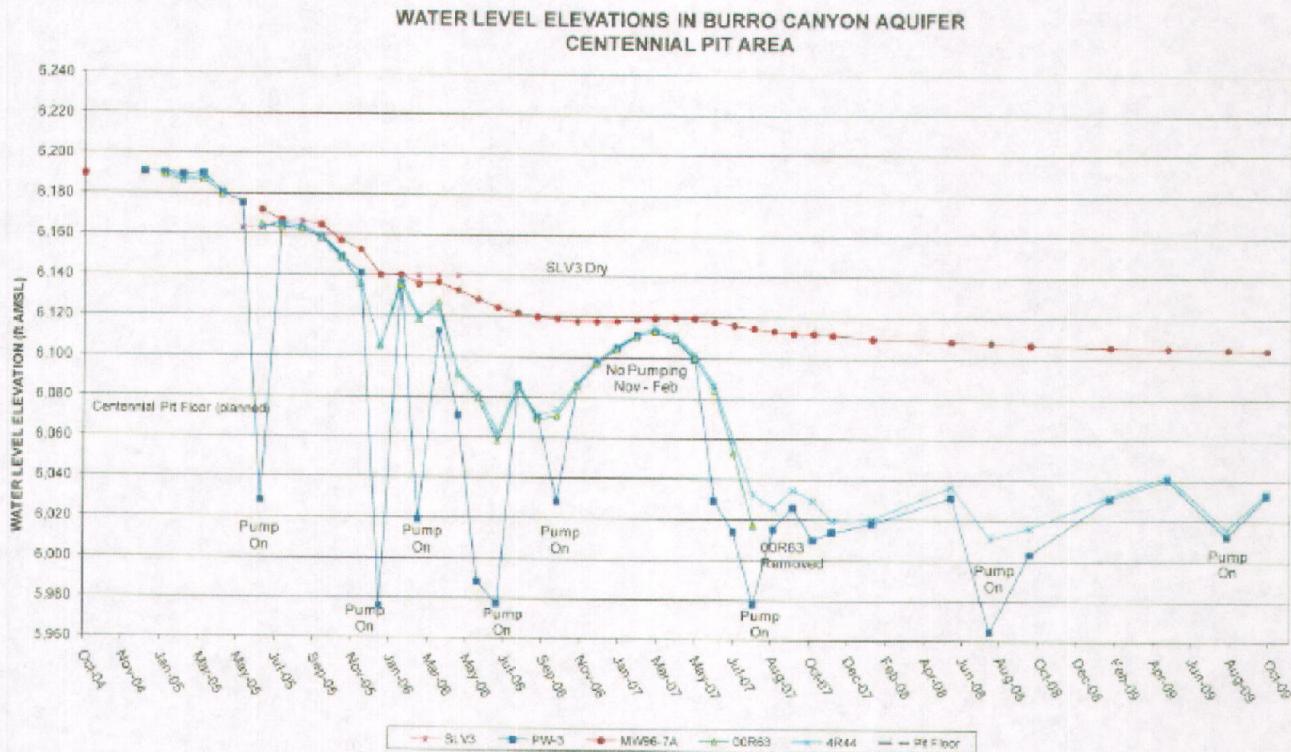


Figure 2. Observed water-levels from monitoring and pumping wells near the Lisbon Valley Copper Mine. Reproduced from the Whestone Associates Inc. report "2009 Annual Update of the Lisbon Valley Hydrogeologic System Evaluation, Prepared for Lisbon Valley Mining Co."



United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Montana Water Science Center

3162 Bozeman Avenue

Helena, MT 59601

To: Rebecca Doolittle, District Geologist, BLM, Moab, UT
From: David Naftz, Research Hydrologist, USGS, Helena, MT
Date: September 9, 2013
Re: **Technical Assistance:** Technical review of "*Updated backfill evaluation for the Centennial Pit at the Lisbon Valley Mine, Utah*"

Thanks for the opportunity to review the subject report. Overall, I have found that the report and associated data are insufficient to support a scientific decision regarding the future quality of groundwater after mining at the Lisbon Valley Mine. My comments pertaining to the geochemical characteristics of the backfill material and resulting post-mining water quality are summarized below.

1. Lisbon Valley Mine has used a variety of static testing methods to predict the long-term groundwater quality after mining. As noted in Maest and Kuipers (2005), static testing methods (e.g. meteoric water mobility procedure) provide little or no information on long-term water quality and should only be used to simulate short term water-rock interactions with rain/snowmelt. The unsuitability of static testing methods is supported by the comparison of water quality between water samples from the Burro Canyon aquifer and the static test results using material from Beds 14 and 15. As shown in table 4 of the report, chemical constituents in the Burro Canyon aquifer are, on average, significantly lower in concentration than water samples from the corresponding static tests (most static test concentrations are below the lower reporting limits).

As part of my review, I evaluated the average chemical composition of water samples from the Burro Canyon aquifer reported in table 4 using the aqueous geochemical model PHREEQC (Parkhurst and Appelo, 1999). Model results indicate that this water is at or close to thermodynamic equilibrium with a number of minerals (see Attachment 1). The results of the Burro Canyon aquifer simulations are only an estimate because no redox information was provided. The disparity between the simulated post-mining water quality from the laboratory simulations and the current water quality of water samples from the Burro Canyon aquifer should be addressed. I am assuming that Lisbon Valley Mine is not proposing that the post-mining water quality will be better than the current/pre-mining water quality.

2. Page 9 and Table 4. The report indicates that a modified meteoric water mobility procedure (MWMP) was used to predict the post-mining water quality of waste rock samples from Beds 14 and 15 (Burro Canyon

Formation). As noted in comment 1, this is not an appropriate procedure to estimate long-term post-mining water quality. Furthermore, only one sample from each bed was tested, yet up to 75 million tons of this material will potentially be backfilled after mining (see tables 2 and 3). Aside from this static test being unsuitable to predict long-term post-mining groundwater quality, testing one sample from each bed cannot represent the range of material (e.g. grain size, post-mining weathering conditions, mineralogy, etc...) that will ultimately be backfilled and exposed to incoming groundwater and meteoric water after mining. A statistically based sampling design is needed to insure that an adequate number of samples have been collected and properly analyzed to determine the full range of geologic materials have been tested. Additional MWMP samples were processed from other waste rock materials (see table 5); however, these were single pass extracts with variable pH values for the extract solutions and it is questionable whether these results can be compared to the most recent MWMP results.

3. It is unclear from the supporting information for the MWMP tests as to the degree of weathering the materials used in the tests have undergone. Because the purpose of MWMP tests is to represent the rapid release of soluble salts from weathered surfaces of backfill materials, it is important to confirm the weathered state of this material. It is noted in table 4 that 97.1% of the material used from Bed 15 had particle diameters > 5 cm. If the MWMP procedure was applied correctly, all particles > 5 cm in diameter are supposed to be broken into smaller sized particles. The combination of the large proportion of large particles (> 5 cm in diameter) coupled with the exposure of non-weathered surfaces from the hand breaking of particles invalidates the MWMP results by exposing non-weathered surfaces; resulting in an underestimation of the mass of solutes than would be expected.
4. I apologize if I missed this during my review; however, I saw no mention of a QA/QC plan or the QA/QC results associated with the laboratory tests provided in the report. This information (e.g. standard reference material, laboratory accreditation, method blanks, sample replicates, etc...) should be provided to validate the results.
5. Given the deficiencies of the static tests that were outlined in the previous comments, kinetic tests should be conducted on representative and well characterized backfill material to provide scientifically defensible predictions of long-term, post-mining groundwater quality. To facilitate this work, I suggest that Lisbon Valley Mine or their designated consultant submit a workplan outlining the kinetic tests that can be reviewed for acceptance by BLM prior to executing the tests.

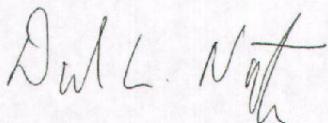
In my opinion, the current version of this report does not contain sufficient data to reasonably predict long-term post-mining groundwater quality at the Lisbon Valley Mine. Please feel free to contact me (email: dlnaftz@usgs.gov; phone: 406-457-5945) if you have any questions or need further clarification on my review of the subject document.

References

Maest, A.S., and Kuipers, J.R., 2005, Predicting water quality at hardrock mines: Methods and models, uncertainties, and state-of-the-art. Accessed April 12, 2013, at URL <http://pebblescience.org/Pebble-Mine/acid-drainage-pdfs/PredictionsReportFinal.pdf>

Parkhurst, D.L. and Appelo, C.A.J., 1999, User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.

Sincerely,



David L. Naftz, Ph.D.
Research Hydrologist

Copy to: Terry Snyder, BLM State Office, Salt Lake City, UT

Attachment

Attachment 1

Input file: D:\Lisbon Valley project\PHREEQC\Burro-Canyon-APR13.pqi
Output file: D:\Lisbon Valley project\PHREEQC\Burro-Canyon-APR13.pqo
Database file: C:\Program Files (x86)\USGS\Phreeqc Interactive
2.18.5570\database\wateq4f.dat

Reading data base.

```
SOLUTION_MASTER_SPECIES
SOLUTION_SPECIES
PHASES
EXCHANGE_MASTER_SPECIES
EXCHANGE_SPECIES
SURFACE_MASTER_SPECIES
SURFACE_SPECIES
RATES
END
```

Reading input data for simulation 1.

DATABASE C:\Program Files (x86)\USGS\Phreeqc Interactive
2.18.5570\database\wateq4f.dat

```
SOLUTION 1 Burro Canyon median concentrations--oxidizing
temp      15
pH        7.1
pe        -5
redox     pe
units     mg/l
density   1
Ba        0.055
Al        0.062
Sb        0.002
As        0.004
Be        0.001
Cd        0.003
Ca        334
Cr        0.003
Cu        0.043
Fe        3.1
Pb        0.002
Mg        127
Mn        0.9
Mo        0.016
Ni        0.015
K         15
Se        0.003
Si        7.1
Na        91
V         0.006
Zn        0.51
U         0.092
Cl        40
```

F 0.4
 S(6) 1111
 Alkalinity 457 gfw 50.04
 water 1 # kg
 END
 WARNING: Could not find element in database, Be.
 Concentration is set to zero.
 WARNING: Could not find element in database, Cr.
 Concentration is set to zero.
 WARNING: Could not find element in database, Mo.
 Concentration is set to zero.
 WARNING: Could not find element in database, Sb.
 Concentration is set to zero.
 WARNING: Could not find element in database, V.
 Concentration is set to zero.

Beginning of initial solution calculations.

Initial solution 1. Burro Canyon median concentrations--oxidizing

-----Solution composition-----

Elements	Molality	Moles
Al	2.303e-006	2.303e-006
Alkalinity	9.153e-003	9.153e-003
As	5.351e-008	5.351e-008
Ba	4.013e-007	4.013e-007
Ca	8.352e-003	8.352e-003
Cd	2.675e-008	2.675e-008
Cl	1.131e-003	1.131e-003
Cu	6.782e-007	6.782e-007
F	2.110e-005	2.110e-005
Fe	5.563e-005	5.563e-005
K	3.845e-004	3.845e-004
Mg	5.235e-003	5.235e-003
Mn	1.642e-005	1.642e-005
Na	3.967e-003	3.967e-003
Ni	2.561e-007	2.561e-007
Pb	9.674e-009	9.674e-009
S(6)	1.159e-002	1.159e-002
Se	3.808e-008	3.808e-008
Si	1.184e-004	1.184e-004
U	3.874e-007	3.874e-007
Zn	7.819e-006	7.819e-006

-----Description of solution-----

pH	=	7.100
pe	=	-5.000
Activity of water	=	0.999
Ionic strength	=	4.291e-002
Mass of water (kg)	=	1.000e+000
Total carbon (mol/kg)	=	1.060e-002
Total CO2 (mol/kg)	=	1.060e-002
Temperature (deg C)	=	15.000

Electrical balance (eq) = -1.791e-003
 Percent error, $100 \times (\text{Cat} - |\text{An}|) / (\text{Cat} + |\text{An}|)$ = -3.57
 Iterations = 10
 Total H = 1.110220e+002
 Total O = 5.558338e+001

-----Distribution of species-----

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma
H+	9.215e-008	7.943e-008	-7.035	-7.100	-0.065
OH-	6.811e-008	5.671e-008	-7.167	-7.246	-0.080
H ₂ O	5.551e+001	9.994e-001	1.744	-0.000	0.000
Al	2.303e-006				
Al(OH) ₄ -	2.037e-006	1.696e-006	-5.691	-5.771	-0.080
Al(OH) ₂ +	1.134e-007	9.439e-008	-6.946	-7.025	-0.080
Al(OH) ₃	7.878e-008	7.957e-008	-7.104	-7.099	0.004
AlF ₂ +	4.852e-008	4.040e-008	-7.314	-7.394	-0.080
AlF ₂	1.141e-008	5.485e-009	-7.943	-8.261	-0.318
AlF ₃	7.729e-009	7.806e-009	-8.112	-8.108	0.004
AlOH ₂	5.034e-009	2.419e-009	-8.298	-8.616	-0.318
AlSO ₄ +	4.921e-010	4.098e-010	-9.308	-9.387	-0.080
Al ₃	1.957e-010	3.763e-011	-9.708	-10.424	-0.716
Al(SO ₄) ₂ -	5.841e-011	4.863e-011	-10.234	-10.313	-0.080
AlF ₄ -	5.775e-011	4.809e-011	-10.238	-10.318	-0.080
AlHSO ₄ +2	5.572e-018	2.678e-018	-17.254	-17.572	-0.318
As(3)	5.351e-008				
H ₃ AsO ₃	5.312e-008	5.364e-008	-7.275	-7.270	0.004
H ₂ AsO ₃ -	3.905e-010	3.251e-010	-9.408	-9.488	-0.080
H ₄ AsO ₃ +	2.536e-015	2.111e-015	-14.596	-14.675	-0.080
HAsO ₃ -2	1.088e-017	5.228e-018	-16.963	-17.282	-0.318
AsO ₃ -3	4.790e-026	9.213e-027	-25.320	-26.036	-0.716
As(5)	1.351e-018				
HAsO ₄ -2	7.977e-019	3.834e-019	-18.098	-18.416	-0.318
H ₂ AsO ₄ -	5.530e-019	4.605e-019	-18.257	-18.337	-0.080
AsO ₄ -3	4.355e-023	8.375e-024	-22.361	-23.077	-0.716
H ₃ AsO ₄	6.546e-024	6.611e-024	-23.184	-23.180	0.004
Ba	4.013e-007				
Ba ₂	2.038e-007	9.796e-008	-6.691	-7.009	-0.318
BaSO ₄	1.914e-007	1.933e-007	-6.718	-6.714	0.004
BaHCO ₃ +	5.938e-009	4.944e-009	-8.226	-8.306	-0.080
BaCO ₃	1.388e-010	1.402e-010	-9.858	-9.853	0.004
BaOH+	5.016e-014	4.176e-014	-13.300	-13.379	-0.080
C(4)	1.060e-002				
HC ₂ O ₃ -	8.593e-003	7.213e-003	-2.066	-2.142	-0.076
CO ₂	1.489e-003	1.504e-003	-2.827	-2.823	0.004
CaHCO ₃ +	2.715e-004	2.260e-004	-3.566	-3.646	-0.080
MgHCO ₃ +	1.852e-004	1.542e-004	-3.732	-3.812	-0.080
CaCO ₃	1.420e-005	1.434e-005	-4.848	-4.843	0.004
FeHCO ₃ +	1.337e-005	1.113e-005	-4.874	-4.953	-0.080
NaHCO ₃	1.301e-005	1.314e-005	-4.886	-4.881	0.004
CO ₃ -2	6.821e-006	3.386e-006	-5.166	-5.470	-0.304
MgCO ₃	5.186e-006	5.237e-006	-5.285	-5.281	0.004
MnHCO ₃ +	3.432e-006	2.858e-006	-5.464	-5.544	-0.080
ZnHCO ₃ +	1.755e-006	1.461e-006	-5.756	-5.835	-0.080
FeCO ₃	1.241e-006	1.253e-006	-5.906	-5.902	0.004

MnCO3	1.184e-006	1.196e-006	-5.927	-5.922	0.004
ZnCO3	1.076e-006	1.087e-006	-5.968	-5.964	0.004
NiCO3	2.184e-007	2.206e-007	-6.661	-6.656	0.004
Zn(CO3)2-2	1.637e-007	7.869e-008	-6.786	-7.104	-0.318
NaCO3-	1.456e-007	1.212e-007	-6.837	-6.916	-0.080
NiHCO3+	1.051e-008	8.750e-009	-7.978	-8.058	-0.080
PbCO3	7.952e-009	8.031e-009	-8.100	-8.095	0.004
BaHCO3+	5.938e-009	4.944e-009	-8.226	-8.306	-0.080
Ni(CO3)2-2	2.701e-009	1.298e-009	-8.569	-8.887	-0.318
CdHCO3+	2.024e-009	1.686e-009	-8.694	-8.773	-0.080
PbHCO3+	9.391e-010	7.819e-010	-9.027	-9.107	-0.080
Pb(CO3)2-2	1.421e-010	6.830e-011	-9.847	-10.166	-0.318
BaCO3	1.388e-010	1.402e-010	-9.858	-9.853	0.004
UO2(CO3)3-4	3.380e-011	1.803e-012	-10.471	-11.744	-1.273
CdCO3	1.968e-011	1.988e-011	-10.706	-10.702	0.004
UO2(CO3)2-2	1.175e-011	5.645e-012	-10.930	-11.248	-0.318
Cd(CO3)2-2	4.428e-013	2.128e-013	-12.354	-12.672	-0.318
CuCO3	1.663e-013	1.680e-013	-12.779	-12.775	0.004
UO2CO3	8.503e-014	8.588e-014	-13.070	-13.066	0.004
U(CO3)4-4	4.100e-014	2.187e-015	-13.387	-14.660	-1.273
CuHCO3+	4.011e-014	3.340e-014	-13.397	-13.476	-0.080
Cu(CO3)2-2	1.490e-015	7.161e-016	-14.827	-15.145	-0.318
U(CO3)5-6	2.112e-017	2.890e-020	-16.675	-19.539	-2.864
UO2(CO3)3-5	2.004e-018	2.056e-020	-17.698	-19.687	-1.989
(UO2)3(CO3)6-6	2.859e-028	3.911e-031	-27.544	-30.408	-2.864
Ca	8.352e-003				
Ca+2	5.968e-003	2.969e-003	-2.224	-2.527	-0.303
CaSO4	2.097e-003	2.118e-003	-2.678	-2.674	0.004
CaHCO3+	2.715e-004	2.260e-004	-3.566	-3.646	-0.080
CaCO3	1.420e-005	1.434e-005	-4.848	-4.843	0.004
CaF+	3.785e-007	3.151e-007	-6.422	-6.502	-0.080
CaOH+	7.446e-009	6.200e-009	-8.128	-8.208	-0.080
CaHSO4+	1.058e-009	8.809e-010	-8.975	-9.055	-0.080
Cd	2.675e-008				
Cd+2	1.538e-008	7.390e-009	-7.813	-8.131	-0.318
CdSO4	7.800e-009	7.877e-009	-8.108	-8.104	0.004
CdHCO3+	2.024e-009	1.686e-009	-8.694	-8.773	-0.080
CdCl+	7.640e-010	6.361e-010	-9.117	-9.196	-0.080
Cd(SO4)2-2	7.539e-010	3.623e-010	-9.123	-9.441	-0.318
CdCO3	1.968e-011	1.988e-011	-10.706	-10.702	0.004
CdOH+	4.312e-012	3.590e-012	-11.365	-11.445	-0.080
CdOHC1	2.625e-012	2.651e-012	-11.581	-11.577	0.004
CdCl2	2.359e-012	2.382e-012	-11.627	-11.623	0.004
CdF+	1.733e-012	1.443e-012	-11.761	-11.841	-0.080
Cd(CO3)2-2	4.428e-013	2.128e-013	-12.354	-12.672	-0.318
Cd(OH)2	5.173e-015	5.225e-015	-14.286	-14.282	0.004
CdCl3-	1.441e-015	1.200e-015	-14.841	-14.921	-0.080
CdF2	5.566e-017	5.621e-017	-16.254	-16.250	0.004
Cd2OH+3	7.685e-019	1.478e-019	-18.114	-18.830	-0.716
Cd(OH)3-	8.858e-021	7.375e-021	-20.053	-20.132	-0.080
Cd(OH)4-2	1.721e-027	8.270e-028	-26.764	-27.082	-0.318
Cl	1.131e-003				
Cl-	1.130e-003	9.331e-004	-2.947	-3.030	-0.083
CuCl2-	1.492e-007	1.242e-007	-6.826	-6.906	-0.080
FeCl+	2.387e-008	1.988e-008	-7.622	-7.702	-0.080
MnCl+	2.030e-008	1.690e-008	-7.693	-7.772	-0.080
ZnCl+	3.075e-009	2.560e-009	-8.512	-8.592	-0.080

CdCl+	7.640e-010	6.361e-010	-9.117	-9.196	-0.080
ZnOHCl	6.193e-010	6.255e-010	-9.208	-9.204	0.004
CuCl3-2	3.673e-010	1.765e-010	-9.435	-9.753	-0.318
NiCl+	2.474e-011	2.060e-011	-10.607	-10.686	-0.080
MnCl2	6.815e-012	6.883e-012	-11.167	-11.162	0.004
PbCl+	4.711e-012	3.922e-012	-11.327	-11.406	-0.080
CdOHC1	2.625e-012	2.651e-012	-11.581	-11.577	0.004
ZnCl2	2.376e-012	2.400e-012	-11.624	-11.620	0.004
CdCl2	2.359e-012	2.382e-012	-11.627	-11.623	0.004
NiCl2	6.909e-014	6.978e-014	-13.161	-13.156	0.004
PbCl2	6.969e-015	7.038e-015	-14.157	-14.153	0.004
ZnCl3-	2.836e-015	2.361e-015	-14.547	-14.627	-0.080
MnCl3-	2.125e-015	1.769e-015	-14.673	-14.752	-0.080
CdCl3-	1.441e-015	1.200e-015	-14.841	-14.921	-0.080
CuCl+	1.679e-017	1.398e-017	-16.775	-16.855	-0.080
PbCl3-	5.878e-018	4.894e-018	-17.231	-17.310	-0.080
ZnCl4-2	2.117e-018	1.017e-018	-17.674	-17.993	-0.318
UO2Cl+	9.460e-021	7.876e-021	-20.024	-20.104	-0.080
CuCl2	6.202e-021	6.263e-021	-20.207	-20.203	0.004
PbCl4-2	4.199e-021	2.018e-021	-20.377	-20.695	-0.318
UO2Cl2	3.538e-025	3.573e-025	-24.451	-24.447	0.004
FeCl+2	3.531e-025	1.697e-025	-24.452	-24.770	-0.318
CuCl3-	2.073e-026	1.726e-026	-25.683	-25.763	-0.080
UCl+3	6.958e-027	1.338e-027	-26.158	-26.873	-0.716
FeCl2+	1.179e-027	9.818e-028	-26.928	-27.008	-0.080
CuCl4-2	1.322e-031	6.353e-032	-30.879	-31.197	-0.318
FeCl3	9.071e-032	9.161e-032	-31.042	-31.038	0.004
Cu(1)	6.782e-007				
Cu+	5.286e-007	4.401e-007	-6.277	-6.356	-0.080
CuCl2-	1.492e-007	1.242e-007	-6.826	-6.906	-0.080
CuCl3-2	3.673e-010	1.765e-010	-9.435	-9.753	-0.318
Cu(2)	2.657e-013				
CuCO3	1.663e-013	1.680e-013	-12.779	-12.775	0.004
CuHCO3+	4.011e-014	3.340e-014	-13.397	-13.476	-0.080
Cu(OH)2	3.025e-014	3.055e-014	-13.519	-13.515	0.004
Cu+2	1.922e-014	9.238e-015	-13.716	-14.034	-0.318
CuSO4	6.847e-015	6.915e-015	-14.165	-14.160	0.004
Cu(CO3)2-2	1.490e-015	7.161e-016	-14.827	-15.145	-0.318
CuOH+	1.396e-015	1.162e-015	-14.855	-14.935	-0.080
CuCl+	1.679e-017	1.398e-017	-16.775	-16.855	-0.080
CuF+	2.848e-018	2.371e-018	-17.545	-17.625	-0.080
Cu(OH)3-	2.782e-020	2.316e-020	-19.556	-19.635	-0.080
CuCl2	6.202e-021	6.263e-021	-20.207	-20.203	0.004
Cu2(OH)2+2	4.402e-025	2.116e-025	-24.356	-24.675	-0.318
Cu(OH)4-2	1.210e-025	5.814e-026	-24.917	-25.236	-0.318
CuCl3-	2.073e-026	1.726e-026	-25.683	-25.763	-0.080
CuCl4-2	1.322e-031	6.353e-032	-30.879	-31.197	-0.318
F	2.110e-005				
F-	1.863e-005	1.551e-005	-4.730	-4.809	-0.080
MgF+	1.928e-006	1.606e-006	-5.715	-5.794	-0.080
CaF+	3.785e-007	3.151e-007	-6.422	-6.502	-0.080
AlF2+	4.852e-008	4.040e-008	-7.314	-7.394	-0.080
NaF	2.863e-008	2.892e-008	-7.543	-7.539	0.004
AlF+2	1.141e-008	5.485e-009	-7.943	-8.261	-0.318
AlF3	7.729e-009	7.806e-009	-8.112	-8.108	0.004
FeF+	2.874e-009	2.393e-009	-8.541	-8.621	-0.080
HF	1.534e-009	1.549e-009	-8.814	-8.810	0.004

MnF+	5.729e-010	4.770e-010	-9.242	-9.321	-0.080	
ZnF+	3.717e-010	3.095e-010	-9.430	-9.509	-0.080	
AlF4-	5.775e-011	4.809e-011	-10.238	-10.318	-0.080	
NiF+	3.266e-012	2.719e-012	-11.486	-11.566	-0.080	
CdF+	1.733e-012	1.443e-012	-11.761	-11.841	-0.080	
HF2-	1.012e-013	8.423e-014	-12.995	-13.075	-0.080	
PbF+	4.521e-014	3.764e-014	-13.345	-13.424	-0.080	
CdF2	5.566e-017	5.621e-017	-16.254	-16.250	0.004	
UO2F+	1.427e-017	1.188e-017	-16.846	-16.925	-0.080	
PbF2	1.180e-017	1.192e-017	-16.928	-16.924	0.004	
H2F2	8.809e-018	8.896e-018	-17.055	-17.051	0.004	
CuF+	2.848e-018	2.371e-018	-17.545	-17.625	-0.080	
UO2F2	6.151e-019	6.212e-019	-18.211	-18.207	0.004	
UF3+	3.715e-019	3.093e-019	-18.430	-18.510	-0.080	
UF2+2	1.823e-019	8.763e-020	-18.739	-19.057	-0.318	
UF4	3.994e-020	4.033e-020	-19.399	-19.394	0.004	
UF+3	3.637e-021	6.995e-022	-20.439	-21.155	-0.716	
UO2F3-	2.197e-021	1.829e-021	-20.658	-20.738	-0.080	
PbF3-	1.609e-021	1.339e-021	-20.794	-20.873	-0.080	
FeF2+	3.650e-022	1.754e-022	-21.438	-21.756	-0.318	
FeF2+	1.150e-022	9.578e-023	-21.939	-22.019	-0.080	
UF5-	1.739e-023	1.448e-023	-22.760	-22.839	-0.080	
FeF3	2.251e-024	2.273e-024	-23.648	-23.643	0.004	
UO2F4-2	3.833e-025	1.842e-025	-24.416	-24.735	-0.318	
UF6-2	6.295e-026	3.025e-026	-25.201	-25.519	-0.318	
PbF4-2	2.069e-026	9.942e-027	-25.684	-26.003	-0.318	
SiF6-2	5.416e-031	2.603e-031	-30.266	-30.585	-0.318	
Fe(2)	5.563e-005					
Fe+2	3.211e-005	1.543e-005	-4.493	-4.812	-0.318	
FeHCO3+	1.337e-005	1.113e-005	-4.874	-4.953	-0.080	
FeSO4	8.855e-006	8.942e-006	-5.053	-5.049	0.004	
FeCO3	1.241e-006	1.253e-006	-5.906	-5.902	0.004	
FeOH+	3.403e-008	2.834e-008	-7.468	-7.548	-0.080	
FeCl+	2.387e-008	1.988e-008	-7.622	-7.702	-0.080	
FeF+	2.874e-009	2.393e-009	-8.541	-8.621	-0.080	
FeHSO4+	5.498e-012	4.578e-012	-11.260	-11.339	-0.080	
Fe(OH)2	1.222e-012	1.234e-012	-11.913	-11.909	0.004	
Fe(OH)3-	6.257e-016	5.209e-016	-15.204	-15.283	-0.080	
Fe(3)	2.320e-015					
Fe(OH)2+	1.248e-015	1.039e-015	-14.904	-14.983	-0.080	
Fe(OH)3	1.062e-015	1.073e-015	-14.974	-14.970	0.004	
Fe(OH)4-	9.753e-018	8.120e-018	-17.011	-17.090	-0.080	
FeOH+2	7.683e-019	3.692e-019	-18.114	-18.433	-0.318	
FeF2+	3.650e-022	1.754e-022	-21.438	-21.756	-0.318	
FeSO4+	3.447e-022	2.870e-022	-21.463	-21.542	-0.080	
FeF2+	1.150e-022	9.578e-023	-21.939	-22.019	-0.080	
Fe+3	4.346e-023	8.359e-024	-22.362	-23.078	-0.716	
Fe(SO4)2-	2.852e-023	2.375e-023	-22.545	-22.624	-0.080	
FeF3	2.251e-024	2.273e-024	-23.648	-23.643	0.004	
FeCl+2	3.531e-025	1.697e-025	-24.452	-24.770	-0.318	
FeCl2+	1.179e-027	9.818e-028	-26.928	-27.008	-0.080	
FeHSO4+2	1.296e-028	6.229e-029	-27.887	-28.206	-0.318	
FeCl3	9.071e-032	9.161e-032	-31.042	-31.038	0.004	
Fe2(OH)2+4	1.055e-034	5.628e-036	-33.977	-35.250	-1.273	
Fe3(OH)4+5	0.000e+000	0.000e+000	-45.510	-47.498	-1.989	
H(0)	9.806e-008					
H2		4.903e-008	4.952e-008	-7.310	-7.305	0.004

K		3.845e-004				
	K+	3.758e-004	3.103e-004	-3.425	-3.508	-0.083
	KSO4-	8.607e-006	7.166e-006	-5.065	-5.145	-0.080
Mg		5.235e-003				
	Mg+2	3.720e-003	1.890e-003	-2.430	-2.724	-0.294
	MgSO4	1.323e-003	1.336e-003	-2.878	-2.874	0.004
	MgHCO3+	1.852e-004	1.542e-004	-3.732	-3.812	-0.080
	MgCO3	5.186e-006	5.237e-006	-5.285	-5.281	0.004
	MgF+	1.928e-006	1.606e-006	-5.715	-5.794	-0.080
	MgOH+	4.073e-008	3.392e-008	-7.390	-7.470	-0.080
Mn (2)		1.642e-005				
	Mn+2	9.250e-006	4.446e-006	-5.034	-5.352	-0.318
	MnHCO3+	3.432e-006	2.858e-006	-5.464	-5.544	-0.080
	MnSO4	2.530e-006	2.555e-006	-5.597	-5.593	0.004
	MnCO3	1.184e-006	1.196e-006	-5.927	-5.922	0.004
	MnCl+	2.030e-008	1.690e-008	-7.693	-7.772	-0.080
	MnOH+	7.428e-010	6.185e-010	-9.129	-9.209	-0.080
	MnF+	5.729e-010	4.770e-010	-9.242	-9.321	-0.080
	MnCl2	6.815e-012	6.883e-012	-11.167	-11.162	0.004
	MnCl3-	2.125e-015	1.769e-015	-14.673	-14.752	-0.080
	Mn(OH)3-	1.685e-019	1.403e-019	-18.773	-18.853	-0.080
Mn (3)		1.576e-036				
	Mn+3	1.576e-036	3.031e-037	-35.802	-36.518	-0.716
Mn (6)		0.000e+000				
	MnO4-2	0.000e+000	0.000e+000	-90.491	-90.809	-0.318
Mn (7)		0.000e+000				
	MnO4-	0.000e+000	0.000e+000	-105.790	-105.870	-0.080
Na		3.967e-003				
	Na+	3.882e-003	3.240e-003	-2.411	-2.489	-0.078
	NaSO4-	7.192e-005	5.988e-005	-4.143	-4.223	-0.080
	NaHCO3	1.301e-005	1.314e-005	-4.886	-4.881	0.004
	NaCO3-	1.456e-007	1.212e-007	-6.837	-6.916	-0.080
	NaF	2.863e-008	2.892e-008	-7.543	-7.539	0.004
Ni		2.561e-007				
	NiCO3	2.184e-007	2.206e-007	-6.661	-6.656	0.004
	Ni+2	1.828e-008	8.787e-009	-7.738	-8.056	-0.318
	NiHCO3+	1.051e-008	8.750e-009	-7.978	-8.058	-0.080
	NiSO4	6.111e-009	6.172e-009	-8.214	-8.210	0.004
	Ni(CO3)2-2	2.701e-009	1.298e-009	-8.569	-8.887	-0.318
	NiCl+	2.474e-011	2.060e-011	-10.607	-10.686	-0.080
	NiOH+	8.855e-012	7.373e-012	-11.053	-11.132	-0.080
	NiF+	3.266e-012	2.719e-012	-11.486	-11.566	-0.080
	Ni(SO4)2-2	2.969e-012	1.427e-012	-11.527	-11.846	-0.318
	Ni(OH)2	1.377e-013	1.391e-013	-12.861	-12.857	0.004
	NiCl2	6.909e-014	6.978e-014	-13.161	-13.156	0.004
	Ni(OH)3-	2.102e-017	1.750e-017	-16.677	-16.757	-0.080
O(0)		0.000e+000				
	O2	0.000e+000	0.000e+000	-81.114	-81.109	0.004
Pb		9.674e-009				
	PbCO3	7.952e-009	8.031e-009	-8.100	-8.095	0.004
	PbHCO3+	9.391e-010	7.819e-010	-9.027	-9.107	-0.080
	PbSO4	2.992e-010	3.022e-010	-9.524	-9.520	0.004
	Pb+2	2.840e-010	1.365e-010	-9.547	-9.865	-0.318
	Pb(CO3)2-2	1.421e-010	6.830e-011	-9.847	-10.166	-0.318
	PbOH+	4.021e-011	3.348e-011	-10.396	-10.475	-0.080
	Pb(SO4)2-2	1.299e-011	6.245e-012	-10.886	-11.204	-0.318
	PbCl+	4.711e-012	3.922e-012	-11.327	-11.406	-0.080

Pb(OH)2	1.623e-013	1.639e-013	-12.790	-12.786	0.004
PbF+	4.521e-014	3.764e-014	-13.345	-13.424	-0.080
PbCl2	6.969e-015	7.038e-015	-14.157	-14.153	0.004
Pb(OH)3-	2.843e-017	2.367e-017	-16.546	-16.626	-0.080
PbF2	1.180e-017	1.192e-017	-16.928	-16.924	0.004
PbCl3-	5.878e-018	4.894e-018	-17.231	-17.310	-0.080
Pb2OH+3	5.319e-019	1.023e-019	-18.274	-18.990	-0.716
PbCl4-2	4.199e-021	2.018e-021	-20.377	-20.695	-0.318
PbF3-	1.609e-021	1.339e-021	-20.794	-20.873	-0.080
Pb(OH)4-2	1.420e-021	6.822e-022	-20.848	-21.166	-0.318
Pb3(OH)4+2	3.700e-026	1.778e-026	-25.432	-25.750	-0.318
PbF4-2	2.069e-026	9.942e-027	-25.684	-26.003	-0.318
S(6)	1.159e-002				
SO4-2	8.077e-003	3.938e-003	-2.093	-2.405	-0.312
CaSO4	2.097e-003	2.118e-003	-2.678	-2.674	0.004
MgSO4	1.323e-003	1.336e-003	-2.878	-2.874	0.004
NaSO4-	7.192e-005	5.988e-005	-4.143	-4.223	-0.080
FeSO4	8.855e-006	8.942e-006	-5.053	-5.049	0.004
KSO4-	8.607e-006	7.166e-006	-5.065	-5.145	-0.080
MnSO4	2.530e-006	2.555e-006	-5.597	-5.593	0.004
ZnSO4	1.358e-006	1.371e-006	-5.867	-5.863	0.004
BaSO4	1.914e-007	1.933e-007	-6.718	-6.714	0.004
Zn(SO4)2-2	9.891e-008	4.754e-008	-7.005	-7.323	-0.318
HSO4-	2.964e-008	2.468e-008	-7.528	-7.608	-0.080
CdSO4	7.800e-009	7.877e-009	-8.108	-8.104	0.004
NiSO4	6.111e-009	6.172e-009	-8.214	-8.210	0.004
CaHSO4+	1.058e-009	8.809e-010	-8.975	-9.055	-0.080
Cd(SO4)2-2	7.539e-010	3.623e-010	-9.123	-9.441	-0.318
AlSO4+	4.921e-010	4.098e-010	-9.308	-9.387	-0.080
PbSO4	2.992e-010	3.022e-010	-9.524	-9.520	0.004
Al(SO4)2-	5.841e-011	4.863e-011	-10.234	-10.313	-0.080
Pb(SO4)2-2	1.299e-011	6.245e-012	-10.886	-11.204	-0.318
FeHSO4+	5.498e-012	4.578e-012	-11.260	-11.339	-0.080
Ni(SO4)2-2	2.969e-012	1.427e-012	-11.527	-11.846	-0.318
CuSO4	6.847e-015	6.915e-015	-14.165	-14.160	0.004
UO2SO4	2.668e-017	2.694e-017	-16.574	-16.570	0.004
AlHSO4+2	5.572e-018	2.678e-018	-17.254	-17.572	-0.318
UO2(SO4)2-2	1.737e-018	8.347e-019	-17.760	-18.078	-0.318
U(SO4)2	6.440e-021	6.504e-021	-20.191	-20.187	0.004
USO4+2	5.837e-022	2.805e-022	-21.234	-21.552	-0.318
FeSO4+	3.447e-022	2.870e-022	-21.463	-21.542	-0.080
Fe(SO4)2-	2.852e-023	2.375e-023	-22.545	-22.624	-0.080
FeHSO4+2	1.296e-028	6.229e-029	-27.887	-28.206	-0.318
Se(-2)	3.808e-008				
HSe-	3.806e-008	3.169e-008	-7.420	-7.499	-0.080
H2Se	2.145e-011	2.166e-011	-10.669	-10.664	0.004
Se(4)	1.565e-029				
HSeO3-	1.464e-029	1.219e-029	-28.834	-28.914	-0.080
SeO3-2	1.010e-030	4.853e-031	-29.996	-30.314	-0.318
H2SeO3	5.392e-034	5.445e-034	-33.268	-33.264	0.004
Se(6)	0.000e+000				
SeO4-2	0.000e+000	0.000e+000	-56.052	-56.370	-0.318
HSeO4-	0.000e+000	0.000e+000	-61.856	-61.935	-0.080
Si	1.184e-004				
H4SiO4	1.182e-004	1.194e-004	-3.927	-3.923	0.004
H3SiO4-	1.836e-007	1.529e-007	-6.736	-6.816	-0.080
H2SiO4-2	1.364e-013	6.558e-014	-12.865	-13.183	-0.318

SiF6-2	5.416e-031	2.603e-031	-30.266	-30.585	-0.318
U(3)	4.172e-030				
U+3	4.172e-030	8.024e-031	-29.380	-30.096	-0.716
U(4)	3.873e-007				
U(OH)4	3.871e-007	3.910e-007	-6.412	-6.408	0.004
U(OH)3+	1.544e-010	1.286e-010	-9.811	-9.891	-0.080
U(CO3)4-4	4.100e-014	2.187e-015	-13.387	-14.660	-1.273
U(OH)2+2	1.311e-014	6.303e-015	-13.882	-14.200	-0.318
U(CO3)5-6	2.112e-017	2.890e-020	-16.675	-19.539	-2.864
UF3+	3.715e-019	3.093e-019	-18.430	-18.510	-0.080
UOH+3	2.049e-019	3.941e-020	-18.688	-19.404	-0.716
UF2+2	1.823e-019	8.763e-020	-18.739	-19.057	-0.318
UF4	3.994e-020	4.033e-020	-19.399	-19.394	0.004
U(SO4)2	6.440e-021	6.504e-021	-20.191	-20.187	0.004
UF+3	3.637e-021	6.995e-022	-20.439	-21.155	-0.716
USO4+2	5.837e-022	2.805e-022	-21.234	-21.552	-0.318
UF5-	1.739e-023	1.448e-023	-22.760	-22.839	-0.080
U+4	3.926e-025	2.095e-026	-24.406	-25.679	-1.273
UF6-2	6.295e-026	3.025e-026	-25.201	-25.519	-0.318
UC1+3	6.958e-027	1.338e-027	-26.158	-26.873	-0.716
U6(OH)15+9	0.000e+000	0.000e+000	-58.334	-64.778	-6.444
U(5)	2.872e-011				
UO2+	2.872e-011	2.391e-011	-10.542	-10.621	-0.080
UO2(CO3)3-5	2.004e-018	2.056e-020	-17.698	-19.687	-1.989
U(6)	4.563e-011				
UO2(CO3)3-4	3.380e-011	1.803e-012	-10.471	-11.744	-1.273
UO2(CO3)2-2	1.175e-011	5.645e-012	-10.930	-11.248	-0.318
UO2CO3	8.503e-014	8.588e-014	-13.070	-13.066	0.004
UO2(OH)3-	9.626e-016	8.015e-016	-15.017	-15.096	-0.080
UO2OH+	3.190e-016	2.656e-016	-15.496	-15.576	-0.080
UO2SO4	2.668e-017	2.694e-017	-16.574	-16.570	0.004
UO2F+	1.427e-017	1.188e-017	-16.846	-16.925	-0.080
UO2+2	1.327e-017	6.378e-018	-16.877	-17.195	-0.318
UO2(SO4)2-2	1.737e-018	8.347e-019	-17.760	-18.078	-0.318
UO2F2	6.151e-019	6.212e-019	-18.211	-18.207	0.004
UO2Cl+	9.460e-021	7.876e-021	-20.024	-20.104	-0.080
UO2F3-	2.197e-021	1.829e-021	-20.658	-20.738	-0.080
UO2(OH)4-2	3.325e-022	1.598e-022	-21.478	-21.796	-0.318
UO2F4-2	3.833e-025	1.842e-025	-24.416	-24.735	-0.318
UO2C12	3.538e-025	3.573e-025	-24.451	-24.447	0.004
(UO2)2(OH)2+2	1.765e-026	8.485e-027	-25.753	-26.071	-0.318
(UO2)3(CO3)6-6	2.859e-028	3.911e-031	-27.544	-30.408	-2.864
(UO2)2OH+3	5.311e-030	1.021e-030	-29.275	-29.991	-0.716
(UO2)3(OH)5+	6.375e-033	5.308e-033	-32.196	-32.275	-0.080
(UO2)3(OH)7-	1.555e-033	1.295e-033	-32.808	-32.888	-0.080
(UO2)3(OH)4+2	1.703e-035	8.185e-036	-34.769	-35.087	-0.318
(UO2)4(OH)7+	0.000e+000	0.000e+000	-40.904	-40.983	-0.080
Zn	7.819e-006				
Zn+2	3.348e-006	1.609e-006	-5.475	-5.793	-0.318
ZnHCO3+	1.755e-006	1.461e-006	-5.756	-5.835	-0.080
ZnSO4	1.358e-006	1.371e-006	-5.867	-5.863	0.004
ZnCO3	1.076e-006	1.087e-006	-5.968	-5.964	0.004
Zn(CO3)2-2	1.637e-007	7.869e-008	-6.786	-7.104	-0.318
Zn(SO4)2-2	9.891e-008	4.754e-008	-7.005	-7.323	-0.318
ZnOH+	1.216e-008	1.013e-008	-7.915	-7.995	-0.080
Zn(OH)2	3.175e-009	3.206e-009	-8.498	-8.494	0.004
ZnCl+	3.075e-009	2.560e-009	-8.512	-8.592	-0.080

ZnOHCl	6.193e-010	6.255e-010	-9.208	-9.204	0.004
ZnF+	3.717e-010	3.095e-010	-9.430	-9.509	-0.080
ZnCl2	2.376e-012	2.400e-012	-11.624	-11.620	0.004
Zn(OH)3-	1.532e-013	1.276e-013	-12.815	-12.894	-0.080
ZnCl3-	2.836e-015	2.361e-015	-14.547	-14.627	-0.080
ZnCl4-2	2.117e-018	1.017e-018	-17.674	-17.993	-0.318
Zn(OH)4-2	5.292e-019	2.543e-019	-18.276	-18.595	-0.318

-----Saturation indices-----

Phase	SI	log IAP	log KT	
Adularia	0.31	-21.05	-21.36	KAlSi3O8
Al(OH)3(a)	-0.60	10.87	11.47	Al(OH)3
AlAsO4:2H2O	-17.67	-33.50	-15.84	AlAsO4:2H2O
Albite	-1.37	-20.03	-18.66	NaAlSi3O8
AlumK	-13.39	-18.75	-5.35	KAl(SO4)2:12H2O
Alunite	3.13	3.01	-0.12	KAl3(SO4)2(OH)6
Analcime	-2.94	-16.10	-13.16	NaAlSi2O6:H2O
Anglesite	-4.43	-12.27	-7.84	PbSO4
Anhydrite	-0.60	-4.93	-4.34	CaSO4
Annite	8.28	-78.96	-87.23	KFe3AlSi3O10(OH)2
Anorthite	-1.90	-21.91	-20.01	CaAl2Si2O8
Antlerite	-24.40	-16.11	8.29	Cu3(OH)4SO4
Aragonite	0.28	-8.00	-8.28	CaCO3
Arsenolite	-12.98	-14.54	-1.56	As2O3
Artinite	-7.05	3.28	10.33	MgCO3:Mg(OH)2:3H2O
As2O5(cr)	-54.78	-46.36	8.42	As2O5
As_native	-0.34	-13.57	-13.23	As
Atacamite	-17.62	-9.80	7.82	Cu2(OH)3Cl
Azurite	-22.52	-17.99	4.54	Cu3(OH)2(CO3)2
B-UO2(OH)2	-8.89	-3.00	5.89	UO2(OH)2
Ba3(AsO4)2	-16.83	-67.18	-50.35	Ba3(AsO4)2
BaF2	-10.84	-16.63	-5.79	BaF2
Barite	0.73	-9.41	-10.14	BaSO4
Basaluminite	4.19	26.89	22.70	Al4(OH)10SO4
BaSeO3	-30.93	-37.32	-6.39	BaSeO3
Beidellite	3.96	-42.85	-46.81	(NaKMg0.5)0.11Al2.33Si3.67O10(OH)2
Bianchite	-6.44	-8.20	-1.76	ZnSO4:6H2O
Birnessite	-30.55	13.05	43.60	MnO2
Bixbyite	-30.21	-30.44	-0.22	Mn2O3
Boehmite	1.57	10.87	9.30	AlOOH
Brochantite	-31.28	-15.94	15.34	Cu4(OH)6SO4
Brucite	-6.05	11.48	17.53	Mg(OH)2
Bunsenite	-6.91	6.14	13.06	NiO
Ca3(AsO4)2:4w	-34.83	-53.74	-18.91	Ca3(AsO4)2:4H2O
Calcite	0.43	-8.00	-8.43	CaCO3
CaSeO3	-27.24	-32.84	-5.60	CaSeO3
Cd(gamma)	-12.18	1.87	14.05	Cd
Cd(OH)2	-7.58	6.07	13.65	Cd(OH)2
Cd(OH)2(a)	-8.19	6.07	14.26	Cd(OH)2
Cd3(OH)2(SO4)2	-21.71	-15.00	6.71	Cd3(OH)2(SO4)2
Cd3(OH)4SO4	-20.96	1.60	22.56	Cd3(OH)4SO4
Cd4(OH)6SO4	-20.73	7.67	28.40	Cd4(OH)6SO4
CdCl2	-13.63	-14.19	-0.57	CdCl2
CdCl2:2.5H2O	-12.21	-14.19	-1.98	CdCl2:2.5H2O
CdCl2:H2O	-12.53	-14.19	-1.66	CdCl2:H2O

CdF2	-15.02	-17.75	-2.73	CdF2
CdMetal	-12.08	1.87	13.95	Cd
CdOHCl	-7.77	-4.06	3.71	CdOHCl
CdSiO3	-7.34	2.15	9.48	CdSiO3
CdSO4	-10.81	-10.54	0.27	CdSO4
CdSO4:2.7H2O	-8.77	-10.54	-1.76	CdSO4:2.67H2O
CdSO4:H2O	-9.07	-10.54	-1.47	CdSO4:H2O
Cerrusite	-2.08	-15.34	-13.25	PbCO3
Chalcanthite	-13.76	-16.44	-2.68	CuSO4:5H2O
Chalcedony	-0.25	-3.92	-3.67	SiO2
Chlorite14A	-4.87	67.36	72.23	Mg5Al2Si3O10(OH)8
Chlorite7A	-8.34	67.36	75.70	Mg5Al2Si3O10(OH)8
Chrysotile	-6.90	26.58	33.48	Mg3Si2O5(OH)4
Claudetite	-13.03	-14.54	-1.51	As2O3
Clinoenstatite	-4.30	7.55	11.85	MgSiO3
CO2(g)	-1.48	-2.82	-1.34	CO2
Coffinite	6.17	-1.20	-7.37	USiO4
Cotunnite	-11.01	-15.93	-4.91	PbCl2
Cristobalite	-0.20	-3.92	-3.73	SiO2
Cu(OH)2	-8.86	0.17	9.03	Cu(OH)2
Cu2SO4	-13.28	-15.12	-1.83	Cu2SO4
Cu3(AsO4)2:6w	-53.14	-88.26	-35.12	Cu3(AsO4)2:6H2O
CuCO3	-9.87	-19.50	-9.63	CuCO3
CuF	-18.56	-11.17	7.39	CuF
CuF2	-23.37	-23.65	-0.28	CuF2
CuF2:2H2O	-19.20	-23.65	-4.46	CuF2:2H2O
CuMetal	7.84	-1.36	-9.20	Cu
CuOCuSO4	-28.71	-16.27	12.43	CuO:CuSO4
CupricFerrite	-10.26	-3.39	6.86	CuFe2O4
Cuprite	3.20	1.49	-1.71	Cu2O
CuprousFerrite	7.79	-1.03	-8.82	CuFeO2
CuSO4	-19.91	-16.44	3.47	CuSO4
Diaspore	3.37	10.87	7.51	AlOOH
Diopside	-5.41	15.30	20.72	CaMgSi2O6
Dioptase	-10.49	-3.76	6.73	CuSiO3:H2O
Dolomite	0.66	-16.19	-16.85	CaMg(CO3)2
Dolomite(d)	0.07	-16.19	-16.26	CaMg(CO3)2
Epsomite	-2.92	-5.13	-2.21	MgSO4:7H2O
Fe(OH)2.7Cl.3	-1.78	-4.82	-3.04	Fe(OH)2.7Cl0.3
Fe(OH)3(a)	-6.67	-1.78	4.89	Fe(OH)3
Fe2(SeO3)3	-101.67	-137.10	-35.43	Fe2(SeO3)3
Fe3(OH)8	-14.39	5.83	20.22	Fe3(OH)8
FeSe2	2.97	-15.61	-18.58	FeSe2
Fluorite	-1.42	-12.15	-10.73	CaF2
Forsterite	-10.51	19.03	29.54	Mg2SiO4
Gibbsite	2.18	10.87	8.69	Al(OH)3
Goethite	-1.15	-1.78	-0.63	FeOOH
Goslarite	-6.16	-8.20	-2.04	ZnSO4:7H2O
Greenalite	-0.49	20.32	20.81	Fe3Si2O5(OH)4
Gummite	-13.98	-3.00	10.99	UO3
Gypsum	-0.35	-4.93	-4.58	CaSO4:2H2O
H2(g)	-4.20	-7.31	-3.11	H2
H2O(g)	-1.78	-0.00	1.78	H2O
Halite	-7.08	-5.52	1.56	NaCl
Halloysite	0.39	13.90	13.51	Al2Si2O5(OH)4
Hausmannite	-32.85	30.74	63.59	Mn3O4
Hematite	-0.33	-3.56	-3.22	Fe2O3

Huntite	-3.27	-32.58	-29.31	CaMg ₃ (CO ₃) ₄
Hydrocerrusite	-8.88	-26.34	-17.46	Pb(OH) ₂ :2PbCO ₃
Hydromagnesite	-13.87	-21.30	-7.43	Mg ₅ (CO ₃) ₄ (OH) ₂ :4H ₂ O
Illite	3.35	-38.31	-41.66	K _{0.6} Mg _{0.25} Al _{2.3} Si _{3.5} O ₁₀ (OH) ₂
Jarosite(ss)	-25.81	-35.64	-9.83	(K _{0.77} Na _{0.03})(OH) ₂ Fe ₃ (SO ₄) ₂ (OH) ₆
Jarosite-K	-26.54	-34.95	-8.41	KFe ₃ (SO ₄) ₂ (OH) ₆
Jarosite-Na	-29.57	-33.93	-4.36	NaFe ₃ (SO ₄) ₂ (OH) ₆
JarositeH	-34.56	-38.55	-3.99	(H ₃ O)Fe ₃ (SO ₄) ₂ (OH) ₆
Jurbanite	-2.50	-5.73	-3.23	AlOH ₄
Kaolinite	5.57	13.90	8.33	Al ₂ Si ₂ O ₅ (OH) ₄
Kmica	10.24	24.45	14.21	KAl ₃ Si ₃ O ₁₀ (OH) ₂
Langite	-33.74	-15.94	17.80	Cu ₄ (OH) ₆ SO ₄ :H ₂ O
Larnakite	-7.82	-7.93	-0.12	PbO:PbSO ₄
Laumontite	2.21	-29.76	-31.97	CaAl ₂ Si ₄ O ₁₂ :4H ₂ O
Laurionite	-6.42	-5.80	0.62	PbOCl
Leonhardite	12.53	-59.52	-72.05	Ca ₂ Al ₄ Si ₈ O ₂₄ :7H ₂ O
Litharge	-8.80	4.33	13.14	PbO
Magadiite	-8.55	-22.85	-14.30	NaSi ₇ O ₁₃ (OH) ₃ :3H ₂ O
Maghemite	-9.94	-3.56	6.39	Fe ₂ O ₃
Magnesite	-0.32	-8.19	-7.87	MgCO ₃
Magnetite	0.81	5.83	5.02	Fe ₃ O ₄
Malachite	-14.56	-8.91	5.65	Cu ₂ (OH) ₂ CO ₃
Manganite	-14.39	10.95	25.34	MnOOH
Massicot	-9.00	4.33	13.34	PbO
Matlockite	-8.07	-17.70	-9.63	PbClF
Melanothallite	-24.14	-20.09	4.04	CuCl ₂
Melanterite	-4.88	-7.22	-2.34	FeSO ₄ :7H ₂ O
Minium	-59.10	17.20	76.30	Pb ₃ O ₄
Mirabilite	-5.79	-7.39	-1.60	Na ₂ SO ₄ :10H ₂ O
Mn ₂ (SO ₄) ₃	-75.53	-80.25	-4.72	Mn ₂ (SO ₄) ₃
Mn ₃ (AsO ₄) ₂ :8H ₂ O	-33.51	-62.21	-28.71	Mn ₃ (AsO ₄) ₂ :8H ₂ O
MnCl ₂ :4H ₂ O	-13.68	-11.41	2.27	MnCl ₂ :4H ₂ O
MnSO ₄	-10.82	-7.76	3.06	MnSO ₄
Monteponite	-8.33	6.07	14.40	CdO
Montmorillonite-Aberdeen	1.51	-28.18	-29.69	
(HNaK)0.14Mg0.45Fe0.33Al1.47Si3.82O10(OH)2				
Montmorillonite-BelleFourche	2.93	-31.98	-34.91	
(HNaK)0.09Mg0.29Fe0.24Al1.57Si3.93O10(OH)2				
Montmorillonite-Ca	4.06	-42.46	-46.51	Ca _{0.165} Al _{2.33} Si _{3.67} O ₁₀ (OH) ₂
Morenosite	-8.03	-10.46	-2.43	NiSO ₄ :7H ₂ O
Na ₄ UO ₂ (CO ₃) ₃	-27.27	-43.56	-16.29	Na ₄ UO ₂ (CO ₃) ₃
Nahcolite	-3.99	-4.63	-0.64	NaHCO ₃
Nantokite	-2.37	-9.39	-7.01	CuCl
Natron	-8.74	-10.45	-1.71	Na ₂ CO ₃ :10H ₂ O
Nesquehonite	-2.72	-8.19	-5.47	MgCO ₃ :3H ₂ O
Ni(OH) ₂	-3.88	6.14	10.03	Ni(OH) ₂
Ni ₂ SiO ₄	-7.02	8.36	15.39	Ni ₂ SiO ₄
Ni ₃ (AsO ₄) ₂ :8H ₂ O	-44.81	-70.32	-25.51	Ni ₃ (AsO ₄) ₂ :8H ₂ O
Ni ₄ (OH) ₆ SO ₄	-24.03	7.97	32.00	Ni ₄ (OH) ₆ SO ₄
NiCO ₃	-6.94	-13.53	-6.59	NiCO ₃
Nsutite	-29.52	13.05	42.56	MnO ₂
O ₂ (g)	-78.30	-81.11	-2.81	O ₂
Otavite	-1.50	-13.60	-12.10	CdCO ₃
Pb(OH) ₂	-4.17	4.33	8.51	Pb(OH) ₂
Pb ₂ (OH) ₃ Cl	-10.25	-1.46	8.79	Pb ₂ (OH) ₃ Cl
Pb ₂ O(OH) ₂	-17.53	8.67	26.20	PbO:Pb(OH) ₂
Pb ₂ O ₃	-48.17	12.87	61.04	Pb ₂ O ₃

Pb2OCO3	-10.79	-11.00	-0.21	PbO:PbCO3
Pb2SiO4	-15.67	4.75	20.42	Pb2SiO4
Pb3(AsO4)2	-40.35	-75.75	-35.40	Pb3(AsO4)2
Pb3O2CO3	-18.36	-6.67	11.69	PbCO3:2PbO
Pb3O2SO4	-14.53	-3.60	10.93	PbSO4:2PbO
Pb4(OH)6SO4	-20.37	0.73	21.10	Pb4(OH)6SO4
Pb4O3SO4	-22.26	0.73	22.99	PbSO4:3PbO
PbF2	-12.06	-19.48	-7.42	PbF2
PbMetal	-4.12	0.14	4.26	Pb
PbO:0.3H2O	-8.65	4.33	12.98	PbO:0.33H2O
PbSiO3	-7.14	0.41	7.56	PbSiO3
Phillipsite	-0.66	-20.54	-19.87	Na0.5K0.5AlSi3O8:H2O
Phlogopite	-7.25	37.13	44.38	KMg3AlSi3O10(OH)2
Phosgenite	-11.45	-31.26	-19.81	PbCl2:PbCO3
Plattnerite	-42.56	8.53	51.10	PbO2
Portlandite	-11.92	11.67	23.59	Ca(OH)2
Prehnite	-2.20	-14.16	-11.96	Ca2Al2Si3O10(OH)2
Pyrochroite	-6.35	8.85	15.20	Mn(OH)2
Pyrolusite	-29.99	13.05	43.04	MnO2
Pyrophyllite	6.88	-41.43	-48.31	Al2Si4O10(OH)2
Quartz	0.21	-3.92	-4.13	SiO2
Retgersite	-8.39	-10.46	-2.07	NiSO4:6H2O
Rhodochrosite	0.27	-10.82	-11.09	MnCO3
Rhodochrosite(d)	-0.43	-10.82	-10.39	MnCO3
Rutherfordine	-8.25	-22.67	-14.41	UO2CO3
Schoepite	-8.71	-3.00	5.71	UO2(OH)2:H2O
Scorodite	-25.91	-46.16	-20.25	FeAsO4:2H2O
Se(s)	6.92	-10.40	-17.32	Se
SeO2	-36.13	-44.51	-8.38	SeO2
Sepiolite	-4.85	11.18	16.03	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-7.48	11.18	18.66	Mg2Si3O7.5OH:3H2O
Siderite	0.54	-10.28	-10.83	FeCO3
Siderite(d)(3)	0.17	-10.28	-10.45	FeCO3
Silicagel	-0.79	-3.92	-3.13	SiO2
SiO2(a)	-1.13	-3.92	-2.80	SiO2
Smithsonite	-1.37	-11.26	-9.89	ZnCO3
Talc	-3.84	18.74	22.58	Mg3Si4O10(OH)2
Tenorite	-7.84	0.17	8.01	CuO
Thenardite	-7.22	-7.38	-0.16	Na2SO4
Thermonatrite	-10.65	-10.45	0.20	Na2CO3:H2O
Tremolite	-9.69	49.35	59.04	Ca2Mg5Si8O22(OH)2
Trona	-14.74	-15.08	-0.34	NaHCO3:Na2CO3:2H2O
U(OH)2SO4	-10.68	-13.88	-3.20	U(OH)2SO4
U3O8(c)	-6.92	16.56	23.48	U3O8
U4O9(c)	15.89	15.08	-0.81	U4O9
UF4(c)	-26.79	-44.92	-18.13	UF4
UF4:2.5H2O	-17.36	-44.92	-27.56	UF4:2.5H2O
UO2(a)	2.62	2.72	0.10	UO2
UO3(gamma)	-11.21	-3.00	8.21	UO3
Uraninite(c)	7.05	2.72	-4.33	UO2
Uranophane	-19.65	-2.16	17.49	Ca(UO2)2(SiO3OH)2
Wairakite	-2.38	-29.76	-27.37	CaAl2Si4O12:2H2O
Willemite	-3.29	12.89	16.18	Zn2SiO4
Witherite	-3.88	-12.48	-8.60	BaCO3
Zincite(c)	-3.29	8.41	11.70	ZnO
Zincosite	-11.70	-8.20	3.50	ZnSO4
Zn(OH)2-a	-4.04	8.41	12.45	Zn(OH)2

Zn(OH)2-b	-3.34	8.41	11.75	Zn(OH)2
Zn(OH)2-c	-3.79	8.41	12.20	Zn(OH)2
Zn(OH)2-e	-3.09	8.41	11.50	Zn(OH)2
Zn(OH)2-g	-3.30	8.41	11.71	Zn(OH)2
Zn2(OH)2SO4	-7.29	0.21	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-8.52	6.68	15.20	Zn2(OH)3Cl
Zn3(AsO4)2:2.5w	-35.99	-63.54	-27.55	Zn3(AsO4)2:2.5H2O
Zn3O(SO4)2	-28.59	-7.99	20.60	ZnO:2ZnSO4
Zn4(OH)6SO4	-11.38	17.02	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-16.73	21.77	38.50	Zn5(OH)8Cl2
ZnCl2	-19.33	-11.85	7.47	ZnCl2
ZnCO3:H2O	-1.00	-11.26	-10.26	ZnCO3:H2O
ZnF2	-14.22	-15.41	-1.19	ZnF2
ZnMetal	-22.49	4.21	26.69	Zn
ZnO(a)	-2.90	8.41	11.31	ZnO
ZnSiO3	1.09	4.48	3.39	ZnSiO3
ZnSO4:H2O	-7.90	-8.20	-0.30	ZnSO4:H2O

End of simulation.

Reading input data for simulation 2.

End of run.
